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CHEMISTRY: ACIDS AND BASES

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Developed by
J. Frazin and Partners

How the Program Works

The design of this program is intentionally simple so that both student and teacher can easily follow it. The student chooses the problem type that he or she wishes to practice from a series of menus, and is then given instructions that are specific to those problems. As the student answers the questions, the computer monitors the number of right and wrong answers as well as the student's consistency (how many right or wrong in a row). Three correct answers in a row, or an overall success rate of 80 percent, moves the student on to more difficult problems, if possible, or to more of the same type problems if he or she has achieved the highest difficulty level in a specific topic. Similarly, a consistency of three wrong answers in a row moves students on to a lower or more basic problem level for practice. The student moves upward and downward in this manner until he or she chooses to quit the program, or until he or she succeeds at the highest level of the selected problem type.

Specific questions for any one problem type are always chosen randomly from a list of possible compounds or equations. Values that are not constants are chosen at random from a range that is both reasonable and realistic. This combination of several possible compounds or equations with randomly selected numbers offers a very large number of different problems that appear in no special order. Therefore, the same student or two different students should never see the same sequence of problems on different program runs.

This program is intended for drill and practice; therefore, there is little of a tutorial nature offered. There are occasional hints when appropriate, which would be helpful to students when answering problems. In general, however, when a student is consistently unsuccessful, he or she should seek the instructor's help before continuing the program.

Scope, Sequence, and Use

This disk is designed primarily to provide chemistry students with drill and practice in the area of acid/base systems. It is divided into three major sections: 1) solving problems dealing with the application of acid/base equilibrium systems; 2) solving problems dealing with pH and with the equilibrium between water and its ion; and 3) performing acid/base titrations through the use of simulation and then calculating the concentration of an unknown base using the titration data obtained.

The menu for the program is as follows:

1. ACID/BASE EQUILIBRIA
2. EQUILIBRIUM OF WATER—Kw
3. TITRATION SIMULATION

In each of the three sections, students should be able to practice problems without the need of an instructor's presence. The student should, however, be provided with a table of logarithms and a table of equilibrium constants for acids, both of which are included in this teacher's manual. An electronic calculator would also be helpful, though not absolutely necessary.

Since the major emphasis of these materials is to provide drill and practice rather than to serve a tutorial function, there are certain chemical concepts that a student must first be exposed to before he or she can take full advantage of the problems offered in this software package.

What follows represents an exploration of the problem format as well as some of the chemical concepts needed to use this program successfully.

Section A: Acid/Base Equilibria

There are four types of problems in this section, each representing a successively higher level of complexity. The student is asked to select the level at which he or she wants to begin, and is then presented with the problems of that type.

The following menu shows the selections in this section that are available to the student:

1. EQUILIBRIUM EQUATIONS
2. CALCULATING K_A AND [H+]
3. CALCULATING K_A AND pH
4. BUFFERS

The student's movement within this section is either toward more difficult problem types as success increases, or into easier problem types as success decreases. It is also important to note that success in each problem type requires the skills used in the preceding levels.

Level 1: Equilibrium Equations

In the first part of this section, students are asked to recognize the correct K_A or K_B expression for a given equation. For example, the student might be given the following dissociation equation for an acid: $HNO_2 \longrightarrow H^+ + NO_2^{-1}$

The student will then be shown a completed K_A expression and will be asked: Is this the correct expression? Yes, No, or Undecided.

If the student's response was No, and the given expression was not correct, the answer is deleted from the list and another

candidate expression appears. This process is repeated until the correct answer randomly appears. If the student responds incorrectly, he or she will receive an appropriate hint and the opportunity to return to the problem for a new candidate answer. If the student answers Undecided, that form will be retained in the random list of candidate answers and could be represented later.

If a student correctly answers several basic equations, he or she will be given more difficult problems. Consistent success with difficult problems moves the student to the unit submenu, where more difficult problem types may be selected.

In the example presented here, the correct answer is:

$$K_A = \frac{[H^{+1}]\,[NO_2^{-1}]}{[HNO_2]}$$

The student should know that K_A is simply a special symbol for an equilibrium constant. It tells the chemist that he or she is dealing with an acid equilibrium system. The general format for writing any equilibrium constant expression from a given equation is as follows: $wA + xB = yC + zD$

A, B, C, and D represent chemical substances, and w, x, y, and z represent coefficients.

Equilibrium Constant Expression:

$$K = \frac{[C]^y\,[D]^z}{[A]^w\,[B]^x}$$

Writing K_A and K_B expressions is a special application of this more general equilibrium constant definition.

Level 2: Calculating K_A and $[H+]$

In the second part of this section, students will relate K_A to the hydrogen ion concentration. Problems in this part are of two types: 1) given the numerical value for the K_A, calculate the hydrogen ion concentration; and 2) given the hydrogen ion concentration, calculate the numerical value of the K_A. Solutions to both of these problems require algebraic skills. For example: What would be the $[H+]$ of a .1 molar HF? The K_A for HF is 6.7×10^{-4}.

1. Write the dissociation equation for the acid, $HF = H + F$.
2. Write the K_A expression for the acid, $$K_A = \frac{[H+]\,[F^-]}{[HF]}$$
3. Let the $[H+] = x$ and substitute $$6.7 \times 10^{-4} = \frac{[x]\,[x]}{[.1 - x]}$$
4. Solve for x.

In most cases, the value of x is so small that the x in the denominator of the expression above can usually be neglected. If x is large relative to the original concentration of the acid, it cannot be neglected and the quadratic equation formula must be used.

An example of the other type of problem in this part is: The $[H+]$ of a .01 molar solution of H_2S is 3.2×10^{-5}. Find the value of the equilibrium constant for the acid (K_A).

1. Write the dissociation constant expression, $H_2S \longrightarrow H^+ + HS^-$

   In all problems, the student should assume that only one of the available

hydrogen ions dissociates, and that the calculated K_A will be the first dissociation equilibrium constant for the acid.

2. Write the K_A expression,

$$K_A = \frac{[H+][HS^-]}{[H_2S]}$$

3. Substitute,

$$K_A = \frac{[3.2 \times 10^{-5}][3.2 \times 10^{-5}]}{[.01 - (3.2 \times 10^{-5})]}$$

In this case, as in most cases, the value of [H+], which is subtracted in the denominator, may be neglected since it is so small.

In this part, correct answers give students an opportunity to move on to more difficult questions in the next level. Incorrect responses send the student to a level-one problem type. Several correct responses to a level-one problem type return the student to the original question type for more practice.

Level 3: Calculating K_A and pH

The third part of this section involves two types of problems: 1) given the numerical value for the K_A, calculate the pH; and 2) given the pH, calculate the numerical value for the K_A.

Solutions to the problems in this part are very similar to those of level 2 of this section except that, in addition, the concept that pH = $-$Log [H+] must be incorporated. For example: If [H+] = 1×10^{-6}, the pH = $-$Log [1×10^{-6}] or 6. No log table is needed when the coefficient in scientific notation is a 1.

For example: If [H+] = 5×10^{-4}, then the pH = $-$Log [5×10^{-6}] = $-$ [(Log 5) $-$ 4] = 3.3.

A log table or calculator can be used to find the log of 5, which is .7.

The problems in level 3 are essentially the same as those in level 2, except hydrogen ion concentration is taken one step further and is expressed as pH. When working these problems, students will return to level 2 if they answer several questions incorrectly. If the students are then successful, they return to this part to convert [H+] to pH.

Level 4: Buffers

The fourth part of this section is the highest level of problems, the buffer problems. Solving buffer problems involves the same algebraic manipulation of the K_A expression as before, except that the concentration of the buffer ions must also be considered. As with previous problem types, concentrations and compounds will be chosen randomly from a list. If a student incorrectly answers this problem type, he or she is offered a correct solution by the computer, and another problem. Repeated failure returns the student to level 3. Repeated success with problems of the highest difficulty will hold the student at that level until he or she chooses Q to quit and returns to the unit submenu. For example: What would be the [H+] of .1 liters of a .001 molar solution of H_2CO_3 if .1 moles of $NaHCO_3$ is introduced? The K_A for H_2CO_3 is 4.4×10^{-7}.

$$K_A = \frac{[H+][HCO_3^-]}{[H_2CO_3]}$$

$$4.4 \times 10^{-7} = \frac{[H+][.1 \text{ liters}]}{[1 \times 10^{-3}]}$$

$$[H+] = \frac{[4.4 \times 10^{-7}][1 \times 10^{-3}]}{.1}$$

When answering items in the buffer section, students should ignore the effect of the common ion. While in fact the [H+] may actually be affected as a result of this phenomenon, such effects are characteristically small and make problems unnecessarily complex.

Section B: Equilibrium of Water—K_W

This section has three levels of difficulty. Each level is prerequisite for the next higher one. The lowest level includes problems asking for the concentrations of hydrogen and hydroxyl ions in strong acids and bases. The second level asks students to find the pH of an acid or a base with concentrations that are exact powers of ten. Level three offers pH problems where concentrations are not exact powers of ten. The essential difference between levels two and three is the need for log tables; otherwise, these two levels are exactly the same.

The following mènu shows the selections in this section that are available to the student:

1. FINDING [H+] AND [OH−]
2. FINDING pH (NO LOGARITHMS)
3. FINDING pH WITH LOGARITHMS

Level 1: Using the K_W for water

Level 1 problems are basic and require a direct application of the equation:

$K_W = [H+][OH^-] = 1 \times 10^{-14}$

For example: What would be the $[OH^{-1}]$ of a .0001 molar solution of HCl?

HCl is a strong acid that dissociates completely. Therefore, the [H+] of a .0001 molar or 1×10^{-4} M.

$K_W = 1 \times 10^{-14} = [H+][OH^-]$

$K_W = 1 \times 10^{-14} = [1 \times 10^{-4}][OH^-]$

$$[OH^-] = \frac{1 \times 10^{-14}}{1 \times 10^{-4}} = 1 \times 10^{-10}$$

Level 2: Relating pH and [H+]
(exact powers of 10)

These problems require the student to complete the next step of converting hydrogen ion concentrations to pH values. Problems using strong bases are slightly more difficult, requiring the intermediate step of computing [H+] from [OH−]. Concentrations will be chosen randomly and will be limited by reality, but will always be exact powers of 10. Several mistakes at this level results in a display of the solution and a return to level 1 for practice in computing [H+]. For example: What is the pH of a 1×10^{-5} molar solution of H_2SO_4?

In this case, the pH is 5.

Level 3: Relating pH and [H+]
(using log tables)

When the student chooses this level, he or she is presented with the same type of problem that was seen in level 2, except that

concentrations are chosen that will require the use of log tables. Several incorrect answers at this higher level generates a move to level 2 for more practice with an easier problem type. For example: What would be the pH of 2×10^{-5} molar solution of NaOH?

$$1 \times 10^{-14} = [H^+][2 \times 10^{-5}]$$
$$[H^+] = 5 \times 10^{-10}$$
$$pH = -\text{Log}[5 \times 10^{-10}]$$
$$= -[\text{Log } 5 + (-10)] = 9.3$$

In this section, only pH values between 0 and 14 are considered. While other values are theoretically possible, their presence in these exercises would only add unnecessary confusion for many students with no real educational advantage.

Section C: Titration Simulation

The last choice of sections is the titration simulation. This choice is quite different from the two previous sections since it involves a simulation of an important laboratory technique. The student will be allowed to practice nearly all phases of the titration technique. Specifically, the student will be able to:

1. choose the concentration of the standard or base;
2. find the end point by simulating the operation of the buret;
3. read the buret;
4. calculate the molarity.

The student will be asked if he or she wants to choose the concentration of the standard HCl which he will use. If the student answers Yes, he or she will be given several concentrations from which to choose. If the student answers No, then the computer will choose an appropriate concentration.

Once the standard concentration is chosen, a graphic of a full buret and beaker is displayed. The student may add standard HCl to the 40 milliliters of unknown NaOH at either a full flow rate or by drops. When the student indicates that he or she is at an end point, the graphic changes to a closeup of the buret in the range to be read. The student is then asked to read the buret and calculate the molarity of the unknown. After the student has answered, the machine evaluates the result and gives the student a "percent error" with the option of repeating the titration, seeing a correct answer, or trying a new titration.

In performing the calculations for the titration, students should know that at the end point the moles of H^+ ions must equal the moles of OH^- ions.

moles H^+ = normality of acid x liters of acid
moles OH^- = normality of base x liters of base

The equation—normality of acid x volume of acid = normality of base x volume of base—may be useful in solving titration problems.

Instructional Modes

The ways of using the information contained on this disk are limited only by the imagination of the instructor. While the disk is written primarily for the purpose of providing drill and practice for students in solving a variety of different types of problems, there are many educational settings in which the disk can be successfully used. Some suggested uses include:

- Instructors may use the problems on the disk as a source of practice in the normal classroom setting. The large character set used make it possible for students in the class to read the problems easily. Students could be asked to work the problems and give their answers to the teachers, who could then enter the answers into the computer. Students would know instantly whether they had solved the problem correctly. This type of drill and practice would be excellent for preparing for and reviewing for a unit test.
- A variation of the practice above might be to use the computer disk to generate test or quiz questions. A virtually unlimited number of different problems can be generated by the disk. Instructors could generate the quiz problems on the computer in class, or could have the computer provide problems before class begins, which could then be used in more traditional quiz or test situations.
- Another possible use of the disk is to make it available to students outside the normal classroom. If a computer were available to students in a facility such as a computer center, students could use the disk during any available unstructured time to get needed drill and practice on problems. The more problems a student is able to work, the better he or she usually becomes at problem solving. The format of questions on a computer disk is often more appealing to students than is simply working problems in a book. In addition, the menu on the disk is organized so that the student may select the type of problem on which he or she needs the most practice.
- Instructors could also use the computer to generate random problems for makeup testing. Any student who misses a test or quiz could be given a set of original problems to work. This practice may be useful in encouraging academic honesty.
- The titration simulation may be used as prelab preparation for an actual titration, or may be used as a substitute for this type of experiment. In either case, the disk program allows the student to perform the essential steps involved in a titration and to calculate the concentration of an unknown acid or base.

LOGARITHMS

	0	1	2	3	4	5	6	7	8	9
10	0000	0043	0086	0128	0170	0212	0253	0294	0334	0374
11	0414	0453	0492	0531	0569	0607	0645	0682	0719	0755
12	0792	0828	0864	0899	0934	0969	1004	1038	1072	1106
13	1139	1173	1206	1239	1271	1303	1335	1367	1399	1430
14	1461	1492	1523	1553	1584	1614	1644	1673	1703	1732
15	1761	1790	1818	1847	1875	1903	1931	1959	1987	2014
16	2041	2068	2095	2122	2148	2175	2201	2227	2253	2279
17	2304	2330	2355	2380	2405	2430	2455	2480	2504	2529
18	2553	2577	2601	2625	2648	2672	2695	2718	2742	2765
19	2788	2810	2833	2856	2878	2900	2923	2945	2967	2989
20	3010	3032	3054	3075	3096	3118	3139	3160	3181	3201
21	3222	3243	3263	3284	3304	3324	3345	3365	3385	3404
22	3424	3444	3464	3483	3502	3522	3541	3560	3579	3598
23	3617	3636	3655	3674	3692	3711	3729	3747	3766	3784
24	3802	3820	3838	3856	3874	3892	3909	3927	3945	3962
25	3979	3997	4014	4031	4048	4065	4082	4099	4116	4133
26	4150	4166	4183	4200	4216	4232	4249	4265	4281	4298
27	4314	4330	4346	4362	4378	4393	4409	4425	4440	4456
28	4472	4487	4502	4518	4533	4548	4564	4579	4594	4609
29	4624	4639	4654	4669	4683	4698	4713	4728	4742	4757
30	4771	4786	4800	4814	4829	4843	4857	4871	4886	4900
31	4914	4928	4942	4955	4969	4983	4997	5011	5024	5038
32	5051	5065	5079	5092	5105	5119	5132	5145	5159	5172
33	5185	5198	5211	5224	5237	5250	5263	5276	5289	5302
34	5315	5328	5340	5353	5366	5378	5391	5403	5416	5428
35	5441	5453	5465	5478	5490	5502	5514	5527	5539	5551
36	5563	5575	5587	5599	5611	5623	5635	5647	5658	5670
37	5682	5694	5705	5717	5729	5740	5752	5763	5775	5786
38	5798	5809	5821	5832	5843	5855	5866	5877	5888	5899
39	5911	5922	5933	5944	5955	5966	5977	5988	5999	6010
40	6021	6031	6042	6053	6064	6075	6085	6096	6107	6117
41	6128	6138	6149	6160	6170	6180	6191	6201	6212	6222
42	6232	6243	6253	6263	6274	6284	6294	6304	6314	6325
43	6335	6345	6355	6365	6375	6385	6395	6405	6415	6425
44	6435	6444	6454	6464	6474	6484	6493	6503	6513	6522
45	6532	6542	6551	6561	6571	6580	6590	6599	6609	6618
46	6628	6637	6646	6656	6665	6675	6684	6693	6702	6712
47	6721	6730	6739	6749	6758	6767	6776	6785	6794	6803
48	6812	6821	6830	6839	6848	6857	6866	6875	6884	6893
49	6902	6911	6920	6928	6937	6946	6955	6964	6972	6981
50	6990	6998	7007	7016	7024	7033	7042	7050	7059	7067
51	7076	7084	7093	7101	7110	7118	7126	7135	7143	7152
52	7160	7168	7177	7185	7193	7202	7210	7218	7226	7235
53	7243	7251	7259	7267	7275	7284	7292	7300	7308	7316
54	7324	7332	7340	7348	7356	7364	7372	7380	7388	7396

	0	1	2	3	4	5	6	7	8	9
55	7404	7412	7419	7427	7435	7443	7451	7459	7466	7474
56	7482	7490	7497	7505	7513	7520	7528	7536	7543	7551
57	7559	7566	7574	7582	7589	7597	7604	7612	7619	7627
58	7634	7642	7649	7657	7664	7672	7679	7686	7694	7701
59	7709	7716	7723	7731	7738	7745	7752	7760	7767	7774
60	7782	7789	7796	7803	7810	7818	7825	7832	7839	7846
61	7853	7860	7868	7875	7882	7889	7896	7903	7910	7917
62	7924	7931	7938	7945	7952	7959	7966	7973	7980	7987
63	7993	8000	8007	8014	8021	8028	8035	8041	8048	8055
64	8062	8069	8075	8082	8089	8096	8102	8109	8116	8122
65	8129	8136	8142	8149	8156	8162	8169	8176	8182	8189
66	8195	8202	8209	8215	8222	8228	8235	8241	8248	8254
67	8261	8267	8274	8280	8287	8293	8299	8306	8312	8319
68	8325	8331	8338	8344	8351	8357	8363	8370	8376	8382
69	8388	8395	8401	8407	8414	8420	8426	8432	8439	8445
70	8451	8457	8463	8470	8476	8482	8488	8494	8500	8506
71	8513	8519	8525	8531	8537	8543	8549	8555	8561	8567
72	8573	8579	8585	8591	8597	8603	8609	8615	8621	8627
73	8633	8639	8645	8651	8657	8663	8669	8675	8681	8686
74	8692	8698	8704	8710	8716	8722	8727	8733	8739	8745
75	8751	8756	8762	8768	8774	8779	8785	8791	8797	8802
76	8808	8814	8820	8825	8831	8837	8842	8848	8854	8859
77	8865	8871	8876	8882	8887	8893	8899	8904	8910	8915
78	8921	8927	8932	8938	8943	8949	8954	8960	8965	8971
79	8976	8982	8987	8993	8998	9004	9009	9015	9020	9025
80	9031	9036	9042	9047	9053	9058	9063	9069	9074	9079
81	9085	9090	9096	9101	9106	9112	9117	9122	9128	9133
82	9138	9143	9149	9154	9159	9165	9170	9175	9180	9186
83	9191	9196	9201	9206	9212	9217	9222	9227	9232	9238
84	9243	9248	9253	9258	9263	9269	9274	9279	9284	9289
85	9294	9299	9304	9309	9315	9320	9325	9330	9335	9340
86	9345	9350	9355	9360	9365	9370	9375	9380	9385	9390
87	9395	9400	9405	9410	9415	9420	9425	9430	9435	9440
88	9445	9450	9455	9460	9465	9469	9474	9479	9484	9489
89	9494	9499	9504	9509	9513	9518	9523	9528	9533	9538
90	9542	9547	9552	9557	9562	9566	9571	9576	9581	9586
91	9590	9595	9600	9605	9609	9414	9619	9624	9628	9633
92	9638	9643	9647	9652	9657	9661	9666	9671	9675	9680
93	9685	9689	9694	9699	9703	9708	9713	9717	9722	9727
94	9731	9736	9741	9745	9750	9754	9759	9763	9768	9773
95	9777	9782	9786	9791	9795	9800	9805	9809	9814	9818
96	9823	9827	9832	9836	9841	9845	9850	9854	9859	9863
97	9868	9872	9877	9881	9886	9890	9894	9899	9903	9908
98	9912	9917	9921	9926	9930	9934	9939	9943	9948	9952
99	9956	9961	9965	9969	9974	9978	9983	9987	9991	9996

RELATIVE STRENGTHS OF ACIDS IN AQUEOUS SOLUTION AT ROOM TEMPERATURE

All ions are aquated

$HB \rightleftarrows H^+(aq) + B^-(aq) \qquad K_A = \dfrac{[H^+][B^-]}{[HB]}$

ACID	REACTION	K_A
perchloric acid	$HClO_4 \longrightarrow H^+ + ClO_4^-$	very large
hydroiodic acid	$HI \longrightarrow H^+ + I^-$	very large
hydrobromic acid	$HBr \longrightarrow H^+ + Br^-$	very large
hydrochloric acid	$HCl \longrightarrow H^+ + Cl^-$	very large
nitric acid	$HNO_3 \longrightarrow H^+ + NO_3^-$	very large
sulfuric acid	$H_2SO_4 \longrightarrow H^+ + HSO_4^-$	large
hydrated hydrogen ion	$H_3O^+ \longrightarrow H^+ + H_2O$	1.0
oxalic acid	$HOOCCOOH \longrightarrow H^+ + HOOCCOO^-$	5.4×10^{-2}
sulfurous acid ($SO_2 + H_2O$)	$H_2SO_3 \longrightarrow H^+ + HSO_3^-$	1.7×10^{-2}
hydrogen sulfate ion	$HSO_4^- \longrightarrow H^+ + SO_4^{2-}$	1.3×10^{-2}
phosphoric acid	$H_3PO_4 \longrightarrow H^+ + H_2PO_4^-$	7.1×10^{-3}
ferric ion	$Fe(H_2O)_6^{3+} \longrightarrow H^+ + Fe(H_2O)_5(OH)^{2+}$	6×10^{-3}
hydrogen telluride	$H_2Te \longrightarrow H^+ + HTe^-$	2.3×10^{-3}
hydrofluoric acid	$HF \longrightarrow H^+ + F^-$	6.7×10^{-4}
nitrous acid	$HNO_2 \longrightarrow H^+ + NO_2^-$	5.1×10^{-4}
hydrogen selenide	$H_2Se \longrightarrow H^+ + HSe^-$	1.7×10^{-4}
chromic ion	$Cr(H_2O)_6^{3+} \longrightarrow H^+ + Cr(H_2O)_5(OH)^{2+}$	10^{-4}
benzoic acid	$C_6H_5COOH \longrightarrow H^+ + C_6H_5COO^-$	6.6×10^{-5}
hydrogen oxalate ion	$HOOCCOO^- \longrightarrow H^+ + OOCCOO^{2-}$	5.4×10^{-5}
acetic acid	$CH_3COOH \longrightarrow H^+ + CH_3COO^-$	1.8×10^{-5}
aluminum ion	$Al(H_2O)_6^{3+} \longrightarrow H^+ + Al(H_2O)_5(OH)^{2+}$	10^{-5}
carbonic acid ($CO_2 + H_2O$)	$H_2CO_3 \longrightarrow H^+ + HCO_3^-$	4.4×10^{-7}
hydrogen sulfide	$H_2S \longrightarrow H^+ + HS^-$	1.0×10^{-7}
dihydrogen phosphate ion	$H_2PO_4^- \longrightarrow H^+ + HPO_4^{2-}$	6.3×10^{-8}
hydrogen sulfite ion	$HSO_3^- \longrightarrow H^+ + SO_3^{2-}$	6.2×10^{-8}
ammonium ion	$NH_4^+ \longrightarrow H^+ + NH_3$	5.7×10^{-10}
hydrogen carbonate ion	$HCO_3^- \longrightarrow H^+ + CO_3^{2-}$	4.7×10^{-11}
hydrogen telluride ion	$HTe^- \longrightarrow H^+ + Te^{2-}$	10^{-11}
hydrogen peroxide	$H_2O_2 \longrightarrow H^+ + HO_2^-$	2.4×10^{-12}
monohydrogen phosphate ion	$HPO_4^{2-} \longrightarrow H^+ + PO_4^{3-}$	4.4×10^{-13}
hydrogen sulfide ion	$HS^- \longrightarrow H^+ + S^{2-}$	1.3×10^{-13}
water	$H_2O \longrightarrow H^+ + OH^-$	1.8×10^{-16}*
hydroxide ion	$OH^- \longrightarrow H^+ + O^{2-}$	$< 10^{-36}$
ammonia	$NH_3 \longrightarrow H^+ + NH_2^-$	very small

*$K_W = K_A(55.5) = 1 \times 10^{-14}$

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